toria de Tlascala, the *Codex Chimalpopoca*, the *Anales de Cuauhtitlan*, manuscripts of Ixtlilxochitl, Leon y Gama, Father Pichardo, and others. Very curious are the catechisms of the early missionaries written in the Mexican hieroglyphic characters, the maps, charts, plans, "Titulos de Tierra," legal documents, and royal ordinances, throwing light on the early history and settlement of the territory of Mexico.

M. Boban concludes his long and arduous task by adding a comprehensive and well-arranged index to his volumes; and I should not omit to mention that he increases the practical value of his work by inserting a series of biographical notices and many quotations and references to contemporary Mexican archæological literature.

I have reserved the best piece of news to the last. I learn from good authority that it is the intention of the enlightened M. Goupil finally to concede to scholars the access to this marvellous storehouse of American antiquity by placing it in the possession of the Manuscript Department of the Bibliothèque Nationale. Certainly no one in this generation will more deservedly receive the thanks of all genuine Americanists than the donor of such a treasure to public use.

TIME-PERIODS OF THE MAYAS.

BY PROFESSOR CYRUS THOMAS, WASHINGTON, D.C.

IN "Current Notes on Anthropology," *Science*, Feb. 10, reference is made by Dr. Brinton to the article on "Time-Periods of the Mayas," by Dr. Förstemann, in *Globus* (Bd. 63. No. 2). In closing this notice, he remarks that "Dr. Förstemann's discussion of the subject amounts to a demonstration,"—an asserton I think he will find it difficult to maintain. I presume, however, it was based on Dr. Förstemann's well-known ability as an investigator in this line, his long and faithful study of the time-symbols of the Maya Codices, and his great caution in presenting conclusions, rather than on a thorough examination of the data.

I am indebted to Dr. Förstemann for several valuable suggestions in my work in this line;, it was through one of these, given in a private communication, that I was led to the evidence on which I base some of the objections offered here to his conclusions.

He believes that the different steps by which the Mayas reached their final calendar with the year of 365 days, consisting of 18 months of 20 days each, were as follows: First, the period of 20 days, next the period of 18 months, giving the year of 360 days; next, the year of 364 days, formed by adding four days at the end of the eighteenth month, at which time the division into periods of 13 days was introduced; and, finally, the year of 365 days, by adding another day at the end of the eighteenth month. The evidence on which this is based he believes he finds in the Codices, chiefly in the Dresden Codex. He believes he finds evidence of the use of all these years, as also of the Tonalamatl or Sacred year of 260 days in the latter Codex.

We take first his basal or cyclical period:—

1
19
0 } or 14040 days, found in the right column of Dres., p. 73.
0

There is no doubt that this denotes, as he contends, 14040 days, or 39 years, if we count 360 days to the year. "From this," he adds, "proceed two series, of which one has the difference 65, . . . while the other increases by 54." He alludes to the series running through the upper division of pp. 71–73, where the difference is 54; and that running through the middle and lower divisions of the same plates, where the difference is 65 (see our "Aids to the Study of the Maya Codices," pp. 332–337). It is to be noticed, however, that there is no connection between his typical number and these series, and why he has thus referred to them is not apparent. On the contrary, it appears from the 9 Ix below it to belong to the right-hand series of the upper division. I also made the mistake in my "Aids" (p. 337, note) of connecting this 9 Ix with one of the series mentioned.

The point he makes is, that this number is divisible by 360, and that the two series referred to can be explained on this theory, hence it is presumable a year of this length was used in constructing them. Now it must be conceded that if these series can be explained and traced out in accordance with the usual calendar of 365 days to the year, and the four year-series, Dr. Förstemann's argument loses its force, and falls short of a "demonstration."

Let us see if this can be done. For this purpose we present here a part of the series in the middle division of the plates alluded to.

1						
4	19	16	13	9	6	3
15	10	5	0	15	10	5
4 Manik	4 Ik	4 Caban	4 Eb	4 Manik	4 Ik	4 Caban.

This series, which begins with the number and day at the right, ascends, and is to be read from right to left, the difference being 65 days, or 3 months and 5 days, if the numbers are intended to denote days, months, and years. The 19 in the 6th, or next to the left-hand column, is evidently the same as 1 unit of the third order and one of the second, or 1 year, 1 month (counting 360 days to the year). If the year contained only 360 days, it must have commenced year after year with the same day unless there was an arbitrary change. On this theory the numbers in the lower line of numerals (with one exception) might denote the day of the month. For example, Caban would be the 5th day of the month if the year began with Ben, or with Ix counting from the last day of the month; Ik the 10th, Manik the 15th, and so on through the entire series, and also in numerous other series. This would seem to be a sufficient "demonstration" of the theory, and was considered so by me in my "Aids," but the numeral system in the Maya calendar is exceedingly deceptive. Before this is conceded, it is necessary to overcome the following objections: The figures in the middle row do not give the months correctly nor those in the upper the years. The 3, 5, in the first column, really donote the 5th day of the 4th month. While the 1 in the left-hand column, if taken in this way, would refer to the second year. Moreover, if the numbers in the "month" and "day lines" were intended to denote the numbers of the months and days of the months there could be no blanks, such as we see in the 4th column above (13 0). That the symbol represented by the cipher signifies "nothing," is admitted by Dr. Förstemann, and is proven by the number in the month line. As upon the theory of 360 days to the year, all the years should begin with the same day, while this method of counting time remained in vogue, the different series based upon this method should be referred to years commencing with the same day. This, however, is not the case, as the series now under consideration pertains to a year commencing with Ben; while the long series on pp. 52–58 can be reckoned only in years beginning with Lamat. Nor is it possible to bring these series into harmony in this respect upon the theory of a year of 360 days unless we assume there were arbitrary changes, which amounts to begging the question. It is also inconsistent with this theory that the series on pp. 63–64, which Dr. Förstemann believes to be founded on the year of 364 days, gives precisely the same results in the respect mentioned as the other series referred to. In truth, it is impossible that the "day" and "month lines" of numerals should indicate the days of the month and numbers of the months throughout a series extending over several years, except upon the theory of 360 days to the year. We are forced, therefore, to the conclusion, even on Dr. Förstemann's theory, that these series are only successions of intervals in which the columns of numerals simply denote the sum of these intervals at the various steps.

We will now proceed in our attempt to explain the series on pp. 71–73, of which a portion is given above, by the usual calendar system of 365 days to the year and the four year-series. No difference between the two systems will appear until we reach the end of the first year of the series. As this is reached in passing from the 5th to the 6th column, {16 5 4 Caban} and {19 10 4 Ik,} we start with 4 Caban of the 5th column. As before stated, this series proceeds from right to left and is to be counted from the

last day of the month — or these days considered as the first of the month, as Dr. Seler concludes As Caban, counting in this way, is the 5th day of the month in Ben (Ix) years, we take it as our starting point. As the figures in this column ($\begin{matrix}16\\5\end{matrix}$) show that 16 months and 5 days, or 325 days, have been counted up to this point, our 4 Caban must be the 5th day of the 17th month. It follows from this that the starting-point of the series is 5 Ben and that the year is 5 Ben (or 5 Ix, counting from the last day of the preceding month). If there are 365 days in a year there will be 40 days (out of the 65) to count in this year and 25 in the next. As the year (including the 5 added days) will end on 5 Caban, the next will begin with 6 Ezanab (a Cauac year). Counting forward 25 days in this year, we reach 4 Ik, which is the day under the 6th column, but it is the 5th and not the 10th day of the month. This is not an accidental hit, but has been found true in all these series so far as I have tested them, except that in some the months begin with the usual days as the series on pp. 63–64.

But this is not all, the same result will be obtained in the series we are examining if we start with 4 Caban of either of the other three years, except that 4 Ik in the Kan (Akbal) years will fall on the 20th day of the month, in Muluc (Lamat) years on the 15th, and in Ix (Ben) years on the 10th.

It follows, therefore, that these series can be traced and explained as well upon the theory of 365 days to the year as 360. That the series on pp. 46–50 can only be followed out on the usual calendar system is admitted by Dr. Förstemann, and it was through a suggestion he kindly gave me a year or two ago that I was induced to examine it on this theory.

Is it therefore legitimate, in view of these conflicting results based upon the Codex and Calendar, to say that Dr. Förstemann's discussion "amounts to a demonstration?" Does not what has been shown do away with his conclusions so far as they are based upon the supposed year of 360 days? If all the series susceptible of being tested can be explained satisfactorily in conformity with the usual Calendar, is there any necessity of resorting to any other theory?

It is somewhat strange that Dr. Förstemann should consider the series we have been referring to, the sum total of which is $\left\{\begin{matrix}5\\1\\0\end{matrix}\right.$ or 1820 days, as based on the year of 360 days; and yet refer that on pp. 63–64, which has precisely the same sum total, to the year of 364 days. Both are divisible by 364 and neither by 360, and the numerals in both are given on the same plan, the only difference being that in one case the intervals are 65 and in the other 91. Is this a sufficient basis upon which to found the theory of such a radical change in the calendar system? Yet it seems to be the only foundation for this conclusion. That there must have been steps of improvement in the calendar to bring it nearer and nearer the true year is admitted, but is it likely that these various stages of progress showing years of different length will be found in one and the same Codex? It is only necessary to state that this series can also be counted by the usual calendar. In speaking of the divisors of 364, Dr. Förstemann says: "The number 364 is, however, not merely equal to 4×91, but also 28×13, and this seems to have been the cause of the year being divided into periods of 13 days, as the period of 20 days was a natural divisor of 360 days." As the steps in the formation of the calendar indicate periods of usage of the different years, we must conclude, if this supposition be correct, that the division of the year into periods of 13 days was not in vogue during the time the year of 360 days was in use. Nevertheless, we see by the red numerals attached to the days that it is used in connection with the series on pp. 71–73, which he thinks is based on the year of 360 days. In this we have another illustration of the objections which present themselves to the supposition that years of different length were used in the same calendar.

There is another consideration which, according to the opinion accepted by most archæologists, stands opposed to the idea that the year of 360 days should be found in the Dresden Codex. It is that the time-system used on the Palenque "Tablet of the Cross" is that of the usual calendar except that the count is from the days usually given as the last of the month. This is susceptible of proof beyond any reasonable doubt. If, as is generally supposed, this tablet is one of the oldest records remaining in which calendar dates are used, and antidates the Dresden Codex, is it probable we shall find an older year in the latter?

Dr. Förstemann's suggestion that the series on p. 24 and pp. 46–50, especially those on the latter plates, refer to the revolutions of the planet Venus, appears to rest upon a surer foundation than his theory in regard to the year of 360 days. It is a singular fact that the series on p. 24 is divided into periods of $\left.\begin{matrix}8\\2\\0\end{matrix}\right\}$ or 2920 days, which is an exact multiple of 584; and that the series on pp 46–50 is not only divided into periods of 2920 days, but these are subdivided into periods of 584 days. As will be seen by referring to the plates of the Codex 46–50 or to my "Aids" (p. 298), the red counters at the bottom of each of the five plates are $\begin{matrix}11 & 4 & 12 & 0\\16 & 10 & 10 & 8\end{matrix}$ or 236, 90, 250, and 8, the sum of which is 584, the length of the apparent revolution of the planet Venus. As the numeral series (the word "numeral" is used specially here) runs through five pages, the period 584 being repeated in each, we have a total of $\begin{matrix}8\\2\\0\end{matrix}$ or 2920 days. But the "numeral series" is only one-thirteenth part of the entire series, for when one horizontal *line* of the day columns at the top has been traced through the five pages to its end on p. 50, we return to p. 46 and trace the second *line* through, for they connect according to the red counters, and so continue until we have traced the thirteen lines ending with 1 Ahau, the lower right-hand day-symbol on p. 50. Thus we see that the entire series embraces a period of 37960 days, or exactly 104 years of 365 days, a fact noticed by Dr. Förstemann. Yet this is not all that we find in this respect on these five plates. They contain two other precisely similar series. The one which has been referred to is based on and relates only to the month symbols which form the upper line of the text in the middle division; the next, using the same series of days and numerals, is connected with the month symbols forming the upper line of the text in the lower division, and the third with the month symbols in the lower line of the lower division. Dr. Förstemann also alludes to these three series. As each series embraces 104 years, we might suppose the three together to form one great cycle, or Ahau-Katun, of 312 years, but, unfortunately, there seems to be no other connection between them than that they are divided into the same intervals and same days. This is evident from the fact that the upper series (not counting back the 11 months and 16 days with which it begins) commences with 3 Cib, the 4th day of the month Yaxkin in the year 11 Ben (or 11 Ix, counting from the last day of the month); the second or middle series from 3 Cib, the 8th day of the month Zac in the year 4 Muluc (or Lamat);[1] the last or lower series with 3 Cib, the 19th day of the year 4 Ezanab (or 4 Cauac, counting from the last day of the month).

If we count back 11 months 16 days from the first date given in each series, thus reaching the initial day, the following singular result is obtained: the first is found to commence with 3 Yimx, the 13th day of the month Mac in the year 10 Muluc (or 14th day, counting from Lamat); the second, on 2 Yimx, the 18th day of the month Kayab in the year 3 Kan (19th day, counting from Akbal); the third, on 2 Ymix, the third day of the month Xul in the year 4 Cauac (4th day, counting from Ezanab). Therefore, if we arrange them to follow one another in time, we shall find an interval between the first and second of 19 years, and between the second and third of 27 years. It is therefore probable that these three series cover substantially the same period, the dates of the different series falling, in most cases, in different months of the same years; or, in other words, that the periods embraced overlap one another. The great length of the series, and their failure to connect, present the chief reasons for doubting Dr. Förstemann's suggestion in regard to their meaning. On the other hand, there is an oft-repeated glyph in the text which seems

[1] It is strange that the author of the Codex has, in this single instance in all these long series, counted from the 1st day of the month.

to give credit to the theory. Notice of this, however, will be reserved for a subsequent paper.

Attention is called again to the series on pp. 63–64, in order to remark that, by counting back from 13 Ix 91 days, we find that the series commences with the first day of the year 12 Kan. Then, by tracing it through, according to the usual year of 365 days, we find that it ends with 13 Akbal, the last day of the year 3 Kan, omitting the five supplemental days at the end. Adding these five days, the total — 1825 — is exactly divisible by 365. However, it seems that the series should be extended 42 days more to include the other days of the last column (see "Aids," p. 330); in which case neither 365, 364, nor 360 would be an exact divisor of the sum total.

We refer next to Dr. Förstemann's theory that the long series on pp. 51–58 refers to the length of the lunar month. As he admits, the number of days, counting to the last, is 11960, though the sum of the intervals between the columns, as shown by the final numeral, is 11958. These intervals are generally 177 days, but 9 of 148 days occur at nearly equal steps, and 6 of 178 at irregular steps. He finds that by multiplying 29 by 3 and 30 by 3 and adding together the products he obtains 177; that the sum of the products of 29 by 2 and 30 by 3 is 148. To obtain the 178, he finds it necessary to arbitrarily add 1 to the products of 29 by 3 and 30 by 3. Next, he finds that by multiplying 177 by 54 — the number of times this interval occurs in the series — 148 by 9 and 178 by 6, and adding thereto 6, he obtains as the sum of the products 11958. He ascertains in this way that 29 occurs 198 times and that 30 occurs 207 times, making together 405, and that 11958 divided by this sum gives 29.526 days, which falls short of the lunar month but one four-thousandth part of a day. As he adds 6 days to his several products to obtain the number 11958, would it not be as well to add 8 days, making 11960, the true length of the series, which, divided by 405, gives as the quotient 29.53 days, precisely the desired figures?

Notwithstanding my high appreciation of Dr. Förstemann's ability as an investigator, and of his great caution in presenting conclusions, I cannot help thinking that his love for numerical coincidences, created by his long study of the time series of the Dresden Codex, has, in this instance, led him to accept as satisfactory what he would have hesitated to approve had it been presented by any one else. Now, 11960, the true length of the series, embraces precisely 46 periods, or sacred years, of 260 days, so often repeated in the Codices, the whole series and each of these periods commencing with 12 Lamat and ending with 11 Manik, initial and terminal year and month days, according to the method of counting from the last day of the month, which I had not discovered when my "Aids" was written. Is it not, therefore, more reasonable to conclude that the chief relation of the series is to this sacred period? This inquiry is certainly pertinent in view of the fact that neither 29 nor 30 appears singly or in multiple at any point in the series, that the total is first lessened by subtracting 2 and the products increased by the addition of 6. It is proper, however, to admit here that the interval 178, which is an increase by 1 of the usual period of 177 days, is difficult to account for, but such difficulties occur at many points in this Codex, and Dr. Förstemann's attempt at explanation involves so many assumptions as to cause us to hesitate before accepting it.

In order to show the uncertainty of the method adopted in regard to the last mentioned series, we will apply it to one not referred to by Dr. Förstemann, running through the lower division of pp. 30–33. In this case the total sum is 2340 days, and the uniform interval 117. Now if we multiply this interval by 5 we obtain 585, but one day more than the time of the apparent revolution of Venus. Or, if we multiply 584 by 4 and add 4, we obtain 2340, the number of days in the series; and the result is obtained by a less addition than that made by Dr. Förstemann in obtaining the lunar period. Now let us try another experiment in order to find the lunar period, thus: $29 \times 3 + 30 \times 1 = 117$ and 2340 divided by $117 = 20$. This will give us 60 periods of 29 days and 20 of 30 days, and dividing 2340 by 80, the sum total of these, we obtain 29.25 days, lacking only about one-fourth of a day of the correct time. Finally, we observe that 2340 days equal 9 of the sacred years of 260 days each, probably the real basis of the series, as 13 and 20, from which the latter is formed, are both factors here — $9 \times 13 = 117$, $13 \times 20 = 260$, and $260 \times 9 = 2340$.

If we turn to the series on pp. 46–50, in which Dr. Förstemann thinks he finds the Venus period, and apply the method of figuring above alluded to, we shall obtain some curious results. As we have seen, the intervals which together make the 584 days are 236, 90, 250, and 8 days. Are these intervals arbitrary, depending upon arrangements by the priests or by the scribe, or should we infer that they always depend upon the periodicity of certain natural phenomena, and hence form factors or multiples of time-periods? Although the latter may be generally true, the proof of which seems to be the chief object Dr. Förstemann has in view in his mathematical search, yet there are many of the intervals and periods which apparently defy all efforts to fit them into place. That 13, 20, and 18 will most frequently appear is to be expected, as they are always factors, but the coincidences in regard to other supposed time-periods (aside from the ordinary and sacred years) are to be regarded with doubt unless there is something more found than the occasional appearance thereof as factors. For instance, if we take 236, one of the intervals mentioned above, we find that it can readily be made to coincide with the lunar period; thus: $29 \times 4 + 30 \times 4 = 236$. This will give as the time of a revolution 29.5 days, which varies less than an hour from the true period. Yet for all this shall we conclude that here we find allusion to the moon's period? By no means, for this is only a recurring interval; and the others, which go to make up the 584,—the 90, 250, 8,—do not coincide with the moon's revolution or any other known time-period; 90 and 8 are factors of 360, but this number, as we have found, is one of the counters in these series.

The supposition that the revolution of Mercury is indicated by the numerals on p. 24 is certainly based on very slender data. This is found only in the fact that 115, the time of a revolution, is a divisor of the large number 11960, which is a multiple of 260, on which it is doubtless based. Why he has referred in this connection to p. 24 is not apparent. I do not find any relation here between a 1 Ahau and 4 Ahau (the latter is found but once on the page); nor do I find the number alluded to (11960) as the terminus of a series or an interval. There are two series on the page, or one series in which the interval varies. That which occupies the lower three-fifths of the right, commencing at the bottom, running to the left and up, has 2920 as its interval, of which 115 is not a factor. The interval of the other, the terminal columns of which are found at the left below, is 2200. This is not divisible by 115. Therefore, so far as I can see, Dr. Förstemann's only basis for the supposition that the Mayas had ascertained the period of the revolution of Mercury is found in the fact that the large number 11960, which is found several times in the Codex, is divisible by it. Can it be said that a conclusion based on no other evidence than this "amounts to a demonstration?"

That Dr. Förstemann has made progress in the study of the Codices by calling attention to the relations of these numerals to one another is cheerfully admitted, and that he has thrown light upon their meaning and suggested lines of investigation regarding them is undoubtedly true. Yet his discussion in the paper alluded to cannot be considered a "demonstration," when the same data may be used legitimately to lead to quite different results from those he obtains. The explanation which accords with the known Maya Calendar should be accepted in preference to that which requires a radical change, especially when that change is so radical as to wipe out the chief land-marks by which the Mayas were accustomed to reckon time.

Allusion has been made to the method of counting from the last day of the preceding month,— or, as Dr. Seler holds, commencing the months (and hence the years) with the days usually counted the last. Although not essential to the present discussion, we may say in reply to the suggestion which will arise in the mind of the reader, that the first method would necessitate beginning the count of the days from the last day of the preceding year, that this may furnish an explanation of what has hitherto been an unsolved problem — the numbering of the Ahaus. By counting in this way we can readily see why the first Ahau of a Grand Cycle or Ahau-Katun would be numbered 13.